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NEW ISOTOPES AND SYSTEMATICS OF NUCLIDES

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I. Perspective of Discovering New Isotopes and Systematics of Nuclides

When considering the problem of new ways of isotope employment it is not out of place to discuss possibility of obtaining new isotopes as some of them may appear to be useful for solution of vari scientific and practical tasks.

To be a success when searching for new nuclides it is of vital importance that one should correctly predict life time and type of decay being the basic data for choosing the best method of investigation. Yet because of unsufficient knowledge of atomic nucleus structure in detail the nuclear theory cannot reliably predict life time of many unknown nuclides, especially of those belonging to the region of remote transuranium elements where it is difficult not only to predict the periods of half-life but also to trace the region of isotope beta-stability.

Therefore the report deals also with the principles of construction and regularities of rational systematics of nuclides on the basis of which one may predict beta-stable isotopes of transactinides and life time of the hitlerto not discovered isotopes of already known elements.

Nowadays there still remain many blank spaces on the map of isotopes and in the near future one may expect, and with good reason, that a great number of new isotopes of already known and hitherto unknown elements will be discovered. It is worthwhile to mention that almost all beta-readioactive isotopes, the region of stable nuclides is bordered with, have already been discovered; therefore one should not expect appearance of new stable isotopes. All the stable isotopes have already been discovered.

Almost all the beta-stable alfa-radioactive nuclides of known radioactive elements were also discovered. Until

now more than a thousand of beta-radioactive nuclides have been obtained the even greater number of those isotopes will be undoubtedly discovered in the future. The region of beta-radioactive nuclides is limited by instantly decaying neutron-unstable nuclei of β^- -radioactive isotopes and by nuclei possessing one and two-proton radioactivity of β^+ and ε -radioactive isotopes. It is difficult to strictly border the region of beta-radioactive nuclides but approximate calculation proves that several (more) thousands of new beta-radioactive isotopes of the known elements may by discovered. Theoretical calculation made by a number of authors proves that emission of nucleons and alfa-particles in ground and exited states will be typical of many new beta-radioactive nuclides. As one approaches the boundary of beta-radioactive isotope region of β^- -radioactive nuclides new cases of neutron emission after beta-decay appear to be registered, alongside with alfa-decay of neutron-deficient nuclides a number of nuclei with delayed proton-radioactivity that have already been found among Si^{25}, Ne^{17} and a number of non-identified isotopes of varinus elements will be discovered. Also nuclei with one and may be two-proton radioactivity will be obtained.

To discover nuclides located far from the beta-stability region one should design a new method of their obtaining and registering. As the table of isotopes shows the boundary of the known beta-radioactive isotope region passes far away from the stable isotopes of Sr, Kr, and Sn, Sb, Te, I, Xe, Cs elements for those nuclides are appeared as a result of asymmetric fisiion of uranium and thorium.

It appears that more symmetric fission of nuclei caused by particles of high energy may be employed to obtain some new β^- -radioactive isotopes. It is neutron synthesis of those nuclides accompanied by irradiation of the elements with powerful neutron flux in combination with rapid method of identification of shortlived nuclides that would be the universal method of obtaining all the β^--radioactive isotopes.

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Hitherto this method was applied for discovering isotopes of transuranium elements only. The author proposed experiments to discover by a similar method new of comparatively long-lived β^- -radioactive isotopes of stable elements (e.g., Ti 52 and others) . Yet to obtain nuclides of much shorter life time great difficulties connected with their isolation and measuring are to be overcome.

One cannot make use of this method for obtaining neutron-dificient nuclides.

To obtain them two methods are made use of; namely irradiation with heavy multi charged ions and splitting of nuclei by high energy particles.

Making use of these methods and employment of electromagnetic separation of radiosotopes and measuring of their characteristics immediately after irradiation enable a great numbe of new nuclides to be discovered. The experiments have been planned along the lines with employing special separator of radioisotopes, placed directly in the proton beam of high energy and using the method of investigation of millisecond activities that was tried when studying short-lived isomers of Ge^{73}, Te^{115} and others.

Of great interest is the task of discovering new nuclides of hitherto unknown transactinide elements with atomic numbers of $Z > 103$ (1). It is possible that some neutron-deficient isotopes will be obtained by irradiation of a target by heavy ions. But neutron-rich and the majority of beta-stable isotopes of those elements may be obtained by employment of high density neutron fluxes, which may be created in principle in a variety of ways. When conducting these investigations certain regularities of nuclide systematics considered in the next sections of the report may appear to be useful.

It is obvious also that alongside with searching for new isotopes of great importance for the nuclear theory and practical employment is carrying out of investigations on final identification of a number of known nuclides and more thorough study of their characteristics and nuclear-reaction cross-sections according to which they are formed. These

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investigations become much easier when enriched isotopes are used. The results of the author and his collaborators work on the identification of isotopes [2 - 6] lead to a conclusion that successful carrying out of investigations with enriched isotopes being used is limited in a number of cases by insufficient chemical and isotope purity of employed materials. The above circumstance should be taken into consideration when working out technology of enriched isotopes production.

For identification of isotopes and searching for new ones both theoretical calculations and some regularities of nuclide systematics may be used. E.g. half-lives T of the majority of similar (as to the nuclide system) isotopes have close values or are changed with decade periodicity [7]. Besides, the value of T of the isotopes of the same parity (as regards M and N) of one and the same element is regularly decreased as the distance to beta-stability region becomes longer [8]. The author and his scientific workers made a successful use of this regularity when discovering new isotopes of Antimony, Tellurium and other elements [2-6]. The value of T of isomers appears to be also governed by certain periodic regularities that, in particular, enabled isomer of Sn^{113} to be obtained [5].

Making use of those regularities in values of T as well as data of mass and other properties one may predict in most cases life time of new isotopes located not far from the already known nuclides. As the region of the known isotopes extends the number of unknown nuclides for which the value of T may be predicted will increase.

The system of nuclides considered below (Table I) makes it easier to trace the regularities in property alteration of nuclides and therefore it is good to be used when searching for new nuclides. Also it furnishes compact and clear summary of most trustworthy data of isotope properties and may be widely used as a reference book when studying and employing isotopes. This book may be as well recommended as a text-book giving the idea of the variety of the known nuclei as of a single system of nuclides.

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This system makes it easier to understand and remember characteristics of separate nuclides (mass number , mode of transmutation, life time and ...) as their connection with general regularities of nuclei properties are more distinctly visible.

II. Nuclide periodic system

Considering that the principal way of penetrating into the depth of the nucleus is obtaining of as accurate as possible experimental data of separate nuclei. Marie Geppert-Mayer, the designer of the nuclear shell model remarked the following:

"One may hope that various correlations and regularities in these data which will point out certain elementary laws the nucleus structure is submitted to will be brought to light on this way [9].

Actually systematics of nuclei properties in the most direct manner connected with the nucleus structure: mass of 2β-stable isotopes and the neutron (N)-to-proton (Z) ratio in them enables simple and clear regularities to be established. As those regularities are of a periodic nature the systematics of isotopes based upon them may be referred to as "nuclide periodic system". Nowadays elaboration of the nuclide systematics seems to be rather urgent as "today's state of nuclear physica is very much identical to the state of chemistry before the creation of quantum mechanics" [9] and in order to develop the nuclear theory specific peculiarities of masses, abundances, modes of transmutation, decay energy, life-time, level structure and other properties of separate nuclides as well as their interconnection within the system of atomic nuclei. Before starting description of this system it should be noted that in connection with the temptation of drawing an analogy to the periodic system of elements numerous periodic systems of atomic nuclei were suggested in the course of the nearly entire history of the nuclear physics. Yet they neither won the recognition

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nor found use as in the majority of cases they were arbitrary and pretentious to such an extent that did not provide for working out nuclide systematics and resulted in discrediting the very problem of the nucleus system construction. Therefore one may expect that offering of one more periodic system of isotopes would be met with a somewhat biassed and distrusful attitude. The systematics of the recently obtained values of masses and other properties of nuclides show so obvious periodic regularities that one can hardly doubt their truth. In case of lack of data about detailed structure of nuclei the degree of trusthworthiness of the system of nuclides under consideration is determined both by distinctness of periodic regularities in isotopes properties and corroboration of predictions proceeding from it. As the first variant of this system which already contains empiric regularity in correlation of N and Z determining the number of beta-stable isotopes, was published as far back as 1934 now it provides for opportunity to check whether the predictions of new stable isotopes came to be true. All the predicted stable isotopes of even M , except long lived Hf^{182} and Ge^{68} (not included into another table [16]), were later on discovered. They are these: Ar^{38}, Ca^{42}, Ti^{46}, Fe^{58}, Ni^{62}, Zr^{96}, Pd^{102}, $Pd^{104-106}$, Pd^{108}, Cd^{108}, Te^{120}, Xe^{124}, Ba^{132}, Ba^{134}, $Sm^{146-150}$, Sm^{152}, Gd^{152}, $Gd^{154-158}$, Dy^{158}, $Dy^{160-164}$, Er^{164}, $Er^{166-168}$, Er^{170}, $Yb^{170-174}$, Yb^{176}, $Hf^{176-180}$, W^{180}, Pt^{192}, $Pt^{194-196}$, Pt^{198} [17].

Tables of isotopes [16, 17] had been drawn up before the discovery of artificial radioactivity and Mattauch rule failed to be taken into consideration ; therefore in a number of cases the table contains two isobars of M^{odd} instead of one. On account of the above the prediction of M^{odd} isotopes in the table is less single-valued as compared with M^{even} isotopes. In all cases the lower abundance of nuclides of Ni^{62}, Pd^{102}, Cd^{108}, Te^{120}, Xe^{124}, $Ba^{132,134}$, Gd^{152}, Di^{158}, Er^{164}, Yb^{170}, Hf^{176}, W^{180}, Os^{186}, Pt^{192} was corroborated in the table too.

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In the given work registered that special numbers of neutrons (20, 50 and 82) were observed on proton-neutron diagram and it was correctly prdicted that "as regards period of (element) No.59 there are no experimental data and the bend of the curve (bond energy) should be expected" [16]. The tables [7,10,12] drawn up much later and containing isotopes of radioactive elements beta-stable isotopes of uranium and transuranium elements were correctly predicted. U^{236}, $Pn^{242,244}$, Am^{243}, $Cm^{246-248}$, Cm^{250}, Bk^{247}, $Cf^{250-252}$, Cf^{254}, Es^{253}, Fm^{252}, $Fm^{254-258}$. Corroboration of all those predictions could hardly be considered as casual, they testify to the correctness of regularities of the nuclide system. These regularities determine the following basic peculiarities of the system (see tables II and I).

1. On the background of the variety of nuclides isobars with the least mass, stable with respect to both single and double beta-decays and corresponding to normal, most power advantageous combinations of N and Z in atomic nuclei stand out.

2. Increase of M is accompanied by two types of proton and neutron (2n2p and 4n2p) alternation of 2 β-stable nuclides which may be registered after O^{16}.

As far as these groups of nuclides in free state form atomic nuclei of He^4 and He^6 isotopes of helium, such regularity may be called "helion" type of nucleus structure.

A strong difference in the number of isotopes of elements with even and odd atomic numbers is conditioned by this regularity.

3. In the system of nuclides 2β-stable nuclides are divided into periods and half-periods terminated by neutron "magic" nuclei corresponding to nucleon shell and sub-shell filling (in most cases it becomes apparent in bends of the curve of the pair of M^{even} nucleon bond energy, in abundances and other properties of nuclides).

4. Δ N-to-Δ Z ratio of nuclides with Nm (20,50,82, 116,152) arranged in $\Delta Z = 20$, increases according to a rather simple law that permits Nm and structure of pleyade of 2β-stable isotopes of transactinides to be predicted.

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5. Half-lives, decay energy and other properties of beta-radioactive nuclides depend on their position in the system and these properties of analogous nuclides (having the same number of sunplus or deficient neutrons) are periodically changed in the majority of cases [7] .

In principle only one system of nuclides may reflect the atomic nuclei structure, but similar to the Mendeléev Periodic System (which may be represented as a short, a long table and other kinds of table. the nuclide system may be also represented in different variants. It is essential only that 2 β -stable (and analogous) nuclides are singled out the diagram and the periodicity connected with the nuclei Nm pointed out.

Comparison of periodic systems of nuclides and chemical elements shows that they possess common features conditioned by the fact that both: atom shell and its nucleus are of shell structure. Atom shell and nucleus, however, are composed of various particles with different forces acting between them; therefore the systems of atoms and nuclei are also quite different in essence and cannot be reduced to one. On the basis of the periodic system of nuclides one may predict a number of properties of isotopes of hitherto unknown elements with $Z > 103$ and therefore the discovery and study of properties of these elements' β -stable nuclides will be the final test of the system trustworthiness.

III. Beta-stable isotopes of transactidines and the possibility of their forming in outer space

When analysing new ways of radioisotope employment one should not neglect considering the problem of possibility of obtaining not only new isotopes of the known chemical elements but also nuclides of transactidines. If a new economic method for the transactidine synthesis will be discovered which provides for obtaining them in a quantity suitable for practical use, they may be used as new kinds of isotopic heat sources. A necessary prerequisite for discovery and practical employment of transactidines is the existence

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of comparatively long lived nuclides in their structure. Half-lives of β -radioactive isotopes increase in approaching the region of β -stability [8] . A similar picture is observed in the majority of cases of nuclide spontaneous fission. Therefore to predict nuclides of the longest life-time one should find out which transactidine isotopes are likely to be beta-stable. Willer and other scientists spoke about the possibility of checking the impetuous shortening of half-lives of spontaneous fission of the remote transuranium which is still typical of all known nuclides. It was calculated by Yuhanson that half-lives of spontaneous fission of a number of transactidine isotopes would probably range from 1 to 10 days [13] . Such life-time provides for possibility of discovering new elements, e.g. , when they are subject to neutron synthesis.

In addition to the above considerations the data of the isotope systematics are worthy to be used, they may appear to be even more reliable for predicting beta-stable nuclides as they are based on rather simple and general regularity of correlation $\Delta N / \Delta Z$. According to their regularity within every equal interval ($\Delta Z = 20$) between the nuclides of cNm ; $18Ar^{38}_{20}$, $38\ Sr^{88}_{50}$, $58\ Ce^{140}_{82}$, $78\ Pt^{194}_{116}$, $98\ Cf^{250}_{152}$

increment of the neutrons number ΔN is increased by 2 (50-20= = 30, 82-50= 32, 116- 82 = 34, 152-116 = 36) as a result of replacement of 2β -stable nuclides of one helion group 2h2p in the "helion" design by the helion group 4n2p having 2 more neutrons. The correlation of $\Delta N/\Delta Z$ in those periods of isotopes is also increased in a simple succession: $\Delta N/\Delta Z$ = 30:20 = 1.5; 32:20 = 1.6; 34:20 = 1.7 and so on. Basing on this regularity one may expect that between $98\ Cf^{250}_{152}$ and nuclide of $118^{E-Em}\ {}^{308}_{190}$ with a new Nm=190 correlation of $\Delta N / \Delta Z$ will be equal to 1.9. Hence within this interval of beta-stable nuclides there will be only one (the last) helion group 2n2p (α). (the number of an α -group in helion alternation of N and Z may be calculated in terms with the formula [17].

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$$\Delta N_{\alpha} = \frac{3\Delta Z - \Delta M}{2} = \frac{3(118-98) - (308-250)}{2} = \frac{60 - 58}{2} = 1)$$

It is most likely that completion of this single α-group formation after ${}_{98}Cf^{250}$ will be carried out in $\Delta Z = 10$ for nuclide of ${}_{108}E\text{-}Os^{278}$ as it is characteristic of nuclides in the previous half-periods separated from each other by $\Delta Z = 10$. E.g. ${}_{78}Pt^{194}$, ${}_{88}Ra^{222}$, ${}_{98}Cf^{250}$ (see Table III). In conformity with this regularity all transactidine elements of even atomic numbers with $Z = 104-118$ will have three 2β-stable nuclides of M^{even} each (for helion design of 4n2p type) and it is only the 106th or alternatively the 108th element that will have two 2β-stable nuclides of M^{even}: $E - W^{272}$, $E - W^{274}$ or $E - Os^{278}$, $E - Os^{280}$ (for 2n2p design). It should be noted that the obtained on the basis of this regularity value of M of beta-stable and comparatively long-lived nuclides is somewhat lower than a number of values calculated in terms with the extrapolated mass formula and other considerations (Em^{262}, $E - Yb^{265}$, $Lw^{266-268}$, $E - Hf^{271,274}$, $E\text{-}Re^{279}$, $E\text{-}Os^{281-283}$, $E\text{-}Ir^{285}$, $E\text{-}Ir^{287}$, $E\text{-}Pt^{289}$ [13]).

According to the system under consideration all these nuclides are not beta-stable and therefore they will probably have no maximum periods of half-decay. E.g., the highest value of $T_{\frac{1}{2}}$ will be characteristic of Lw^{274} [7], whereas Lw^{265} will be a beta-stable isotope; beta-stable isotope of the 109th element will be ${}_{109}E\text{-}Ir^{281}$, while ${}_{109}E\text{-}Ir^{285,287}$, will be comparatively short-lived β^--radioactive isotopes. One may expect that the values of M of 2β-stable nuclides obtained on the basis of periodical system of isotopes will be corroborated as were proved to be true all the beta-stable isotopes of the elements with $Z = 92-100$ (but Bk^{249}) predicted by the author in 1948-1950 [12]. All beta-stable isotopes of $Z = 101-106$ elements

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(but Cf^{256}) mentioned in this work are given in the table drawn up by G.Siborg [1].

To estimate life time of transforming nuclide prediction of new magic numbers of neutrons is also essential. It is very likely that after yet unknown nuclide with Nm completing period V in the system of isotopes one may expect the same sharp drop of bond energy and reduction of life time of nuclides as were registered after analogous nuclide of Pb^{208} with Nm = 126 period IV is terminated with. If one assumes that period V of the system of isotopes has the same number of elements period IV has, i.e., $\Delta Z = 24$ then this period will be probably terminated with nuclide of $106^{E-W^{274}}$ with Nm = 168. In this case isotope $108^{E-Os^{277-280}}$, for example, as well as $Po^{211-214}$ analogous to it will have very small value of T_{α} and a great deal lesser value of T_{φ} (as compared to T_{φ} obtained without this assumption being taken into account).

For studying the structure of the nucleus determination of the size of the Vth (uncompleted) period of the system of isotopes is of fundamental importance. It would be very useful if this problem could be solved as a result of implementing the program of searching for new transuranium elements.

In the new VIth period of the system of isotopes increase of T of beta-stable isotopes of elements with Z=114-118 is possible, as it is the case with the previous period of elements with Z=90-94 . These nuclides will probably have the longest periods of spontaneous fission. Thus one may suppose that in the region of beta-stable nuclides with Z=106 and Z=114-118 there exist isles of increased stability characterized by comparatively high values of T.

As this suppositions cannot yet be checked experimentally it is interesting at the same time to clear up if there are data of possibility for these nuclide formation in the course of nucleogenesis of transuranium elements in the universe. Proceeding from the hypothesis of formation of transuranium elements nuclides in the course of differentiation of neutron nuclei of stars (or in the course of fast going neutron

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synthesis of elements during the supernew star flashes one may expect that in this case the "isle" of long-lived nuclides with the number of neutrons in nuclei being close to Nm will be primarily formed and maintained. As the spontaneous fission of these nuclides will probably prevail over other types of transmutation stable products of β^--decays of fission fragments in the main, will appear. Their addition to the unprotected isotopes of a number of elements will result in increasing the number of these nuclides and correspondingly to abnormally low abundance of other nuclides, protected from beta-decay products by their isobars of smaller atomic numbers [10]. Actually some 2β-stable nuclides of M^{even} appear to have mysteriously low abundance as compared with neighbouring "unprotected" isotopes of M^{odd}: Te^{124}(4.61%) and Te^{125}(7%), Xe^{128} (1.9%), Xe^{130}(4%) and Xe^{129}(26.5%), Xe^{131} (21.2%), Sm^{148}(11.3%), Sm^{150} (7.5%), and Sm^{147}(15%), Sm^{149}(13.8%), Gd^{154}(2.15%), Gd^{155}(14%), Dy^{160}(2.3%) and Dy^{161}(18.9%), Yb^{170}(3%). At the same time, according to a strongly pronounced regularity in abundance of isotopes, graphically represented in the diagram drawn up by the author [10] and in its new perfected variant, [11] 2β-stable isotopes of M^{even} must have the same (or somewhat higher) abundance as the neighbouring isotopes of M^{odd} have. E.g., Sn^{116}(14.2%), Sn^{118}(24%) and Sn^{117} (7.6%), Sn^{119} (8.6%).

As it was stated in the author's report at the 2nd Geneva Conference [10] this and other anomalies in Te, Xe and Sm isotopes abundance may be explained by addition of beta-decay products of transuranium elements fission fragments only. In that work it was supposed also that anomaly in abundance of those element isotopes was conditioned by fission of Cf^{254}, the exponential of spontaneous fission decay of which coincided according to the data, with the exponential of decreasing the transmission of supernew stars of type I (T = 55 days). However, more precise measurings performed recently proved that Cf^{254} has T = 60.5 days [14] and there-

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fore exponential decrease of the stars transmission must be conditioned by summary curve of Cf^{254} decay and short-lived nuclide or by the fission of more remote transuranium nuclides. As long as measuring [14] of fission fragments yields of Cf^{254} [14] shows that the yield of less propagated Xe^{134} and Xe^{136} is greater than that of more propagated Xe^{132} this will signify that anomaly in abundance of isotopes of Te, Xe and Sm is caused not by the fission of Cf^{254} but by that of heavier nuclides with Z = 106.

To explain an abnormally low abundance of 2β-stable nuclides of M^{even} of lanthanides one should assume that they are formed as a result of fission of isotopes of much heavier elements with Z = 114-118. The element abundance curve plotted by A.P.Vinogradov [15] on the basis of the latest data on chemical composition of Chondrite (which is evidently the closest to the primary abundance of atomic nuclei) and the curve of nuclide abundance [10] show that it is $_{66}Dy^{164}$, $_{67}Ho^{165}$, $_{68}Er^{166}$ isotopes of lanthanide which

reached their peak clearly visible in the plotting.

If assumption is made that those nuclides correspond to the peak of yield of fragments of the heavy component fission while the peak of fragments yield of the light component is located in the region of Ba^{138}, La^{139}, and Ce^{140} with Nm=82 then it appears that these components may be obtained probably as a result of fission of long-living Th^{232} analogous of $_{116}E\text{-}Po^{306}_{190} \rightarrow {}_{58}Ce^{140} + {}_{58}Ce^{164} + 2n$

nuclide. (Ce^{164} on having passed through the β^--decay chain will turn into Dy^{164}) stable nuclide. Obviously some other fragments of heavy and light components will be formed in the course of $116^{E\text{-}Po^{306}}$ fission.

Nuclide abundance curve [10] shows that the peak of Ba^{138}, La^{139}, and Ce^{140} is considerably higher than that of Dy^{164}, Ho^{165} and Er^{166}. Wide abundance of nuclides with Nm = 82 may be explained by additional contribution of fission fragments light transactidines with $Z \simeq 106$ to these

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nuclides abundance which have smaller M and therefore do not produce heavy components of fragments with M=152-172. Recently obtained data/14/ show that a bend between two peaks of the fragments yield curve becomes smaller as M and Z of fissioning nuclide are increased and the lighter component approaches the component with maximum yield of fragments brought by nuclides of Nm=82. Simple extrapolation of this approch of the light component of fragments to the heavy one shows that the light component of nuclides with M=270-280 and Z=106-108 will fuse with the heavy one that will result in a very interesting case of symmetric spon taneous fission of nuclei. This phenomemon is explained by the fact that specific peculiarities conditioned by the end of the period of the isotope system and completion of nucleon shell are most charateristic of nuclides with Nm=82. Therefore in the course of various nuclei fission nuclear core corresponding to the above most clearly pronounced nucleon shell remains, preserved also is a component of fragments corresponding to Nm=82 despite increase of M and a fissioning nucleous.

The other component of fragments at first approaches the component corresponding to nuclides with Nm=82, then they fuse (when $Z \approx 116$).

Thus consideration of anomalies in abundances of lanthanide isotopes probably bring someone to a conclusion that in the course of nucleogenesis of chemical elements in the outer space "isle", comparatively long-life isotopes of transactinides and enable one to hope that investigations of the synthesis of new transactinide elements will be a success. Study of these elements will be of great theoretical importance as it will help to check the above discussed suppositions concern ing beta-stable isotopes of transactinides, new values of Nm and symmetric spontaneous fissions. It is of interest that for some of neutron -deficient nuclides neutron-free symmetric spontaneous fission accompanied by direct formation of fragments of stable isotopes with Nm(e.g., in the course of fission $108^{E-O^{272}} \longrightarrow 2\,{}_{54}Xe^{136}_{82}$) may be assumed. It would be true if the mass defect energy of the fissioning nucleous were completely turned into kinetic energy of these fragments. Existence of such neutron-free, spontaneously fissionable nuclides is an idle fantasy nevertheless this example shows that upon discovering transactinide elements some new and unexpected properties and ways of their use are likely to be found.

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A P P E N D I X

The appendix contains tables illustrating regularities discussed in the report.

In the table I the system of isotopes consisting of two parts (isotopes Z^{odd} and Z^{even}) is given. In this case in the same line nuclides with equal parity only as to N and Z are located, that makes it more convinient to compare values of T and other properties of analogous nuclides. In the middle line (β=0) of the table I the author puts the nuclides with Z=30 corresponding to the maximum of bond energy shown on the curve 2, table II. Therefore the interlocation of nuclides in table I is more unamigous than, for example, in table (10). Such interlocation determines the squeence of the analogous nuclei.

The table shows that after $_8O^{16}$ all the elements of Z^{odd} possess one (or two) β- stable isotopes of M^{odd}, while elements of Z^{even} have more than two isotopes (both M^{odd} and M^{even}).

This regularity is explained by "helion" regularity of the nucleus structure of 2β- stable nuclides. E.g.

$_8O^{16}$+n $\rightarrow$ $_8O^{17}$+ n $\rightarrow$ $_8O^{18}$+ p $\rightarrow$ $_9F^{19}$+ p $_{10}Ne^{20}$+ n (2n2p structure model)
or $_{54}Xe^{128}$+ n $\rightarrow$ $_{54}Xe^{129}$+ n $\rightarrow$ $_{54}Xe^{130}$+ n $\rightarrow$ $_{54}Xe^{131}$+ n $\rightarrow$ $_{54}Xe^{133}$+ p $\rightarrow$
$\rightarrow$ $_{55}Cs^{133}$ + p $\rightarrow$ $_{56}Ba^{134}$+ n ....(4n2p structure model).

The fact that some elements have not one but 2β-stable isotopes of Z^{odd} is explained by the fact that in this point of the system structure of nuclei both according to (2n2p) model and (4n2p) one may be almost equally expected. Lack of beta-stable isotopes of Tc and Pm, appearance of the 3rd stable isotope of tin (Sn^{115}) and other specific peculiarities of a number of elements are conditioned by competition between those two models of the structure.

Helion regularity in alternation of n and p makes itself distinctly felt on the bond energy of nucleon pairs of 2β-stable nuclides shown in table II. It may be seen on the curve that in every period of the system terminated with the nuclide of Nm=20,50,82,126 average value of bond energy is the same. Also bends conditioned by other Nm may be seen on the curve, Table II contains also proton-neutron diagram in which regularity in alternation of structure models (2n2p) and (4n2p) is clearly visible. This regularity causes increase of $\beta N/\beta Z$.

In Mendeleev's Periodical System (Table III) hypothetic values of M beta-stable isotopes of elements with Z=101-118 are given.

Beta-stable isotopes, transmutating upon the emission of alfa-paricles or spontanneously fissionable ones are marked by the point put down near values of M. The value ofM of long-lived or most spread isotopes are underlined. The longest life isotope mass computed in terms with new data is marked with an asterisk. The values of M of 2β-stable isotopes are placed in the middle line in larger print,

Further study of atomic nuclei structure and development of the theory on the basis of the synthesis of ideas of nucleon associations and shells will allow the nature of periodic regularities of the system to the ascertained and the question whether the helion groups are typical of light nuclei or of all atomic nuclei (probably in the perifery layer) to be elucidated.

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SYMBOLS FOR ISOTOPES

48 / 0.185	β-stable, stable
226 α / 1617 л	β-stable, α-radioactive
130 / 10.02 (black)	2β-stable
138 / 0.337 (hatched)	isobar with least nucleus mass
152 / 26.63	2β-stable unreliable
164 / 1.56	least nucleus mass of isobar – unreliable –
257 α, ● ?	hypothetical 2β-stable and α, Ф
260 α ● ?	hypothetical β-stable and α, Ф
6+ / 0.82 c	β^--radioactive
10- / 19.1 c	β^+-radioactive
7- / 53 д	ε-radioactive (electron capture)
121 / 17 ч / 154 д	isomeric transition T_m
-64+ / 12.8 ч	$\beta^-, \beta^+, \varepsilon$
18- / 111 м	β^+, ε
147- α / 24 д	ε, α
249+ α / 314 д	β^-, α

HYPOTHETICAL TYPE OF TRANSFORMATION

168 / 3.3 м	β^-?
159- / 33 м	β^+, ε
150- α / 7 м	ε?

113 + — mass number (A); 4.23 — spreading; 104 м — isomer T_m

3.77 ч / 6.10 л / 4.52 ч — half-life (T): c-second, мс-milli-second, m-minute, Д-day, ч-hour, Г or Л-year; T_m

spontaneous fission of isotopes with Z > 92: 252 / 2.2 г (T_α) / 66 л (T_Φ)

116 / 0.060 — isotope with magic number of neutrons

Z – atomic number of elements
β – number of exceeding(+) or lacking(–) neutrons as compared to average 2β-stable isotope

n	Ia	Ib								2a										2b										3a							
Период	0	I								II										III										IV							
Элемент	He	Be	C	O	Ne	Mg	Si	S	Ar	Ca	Ti	Cr	Fe	Ni	Zn	Ge	Se	Kr	Sr	Zr	Mo	Ru	Pd	Cd	Sn	Te	Xe	Ba	Ce	Nd	Sm	Gd	Dy	Er	Yb	Hf	W
β \ Z	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74
-10	ΔZ=2	ΔZ=4				ΔZ=16								ΔZ=20											ΔZ=20											ΔZ=24	
-18																																					
-17																																					
-16																																					
-15																																					
-14																																					
-13																																	149 ~15 м				
-12																																144- 1 ч	150- α 7 м				
-11																																145- 25 м	151- α 19 м				
-10																									108- 9 м	114- 16 м		126- 97 м				146- 46 д	152- α 2.3 ч	158- 2.5 ч			
-9																									109- 18.1 м	115- 6 м	121- 40 м	127- 12 м	131- 30 м		141- ~1 ч	147- 29 ч	153- α 5 ч				
-8												40- 1.1 с			60- 2.1 м		70- ~44 м	74(-) 12 м	80- 1.8 ч	84(-) 16 М			98- 17 м	104- 59 м	110- 4 ч	116- 2.5 ч	122- 19.5 ч	128- 2.4 д	132- 4.2 ч		142- 72 м	148 α ~130 л	154- α 13 ч	160- 29 ч	164,165 85 м	169,170 112 м	176- 1.7 ч
-7												47- ~0.4 с			61- 1.48 м	65- 1.5 м	71- 4.5 м	75(-) ~5.5 м	81- 29 м	85(-) 15 М 73 М		93- 50 с	99- 21.6 м	105- 55 м	111- 35 м	117- 1.1 ч	123- 1.8 ч	129- 2.45 ч	133- 6.3 ч	137- 55 м	143- 9 м 137 с	149- α 9.3 д	155- 10 ч	161- 3.1 ч		171- 16 ч	177- 130 м
-6												48- ~23 ч	52- 8.3 ч	56- 6.4 д	62- 9.33 ч	66- 150 м	72- 8.4 д	76- 9.7 ч	82- 25.5 д	86- 17 ч	90- 5.7 ч	94- 57 м	100- 4.1 д	106 1.215	112 0.95	118- 6.0 д	124 0.096	130 0.101	134- 72 ч	138- 22 м	144 3.16	150 α 3·10⁵ л	156 0.0524	162 0.136	166- 54 ч	172 ~5 л	178 21.5 д
-5											43- 0.6 с	49- 41.8 м	53- 8.9 м	57- 36 ч	63- 38.3 м	67- 21 м	73- 7.1 ч 44 м	77- 1.2 ч	83- 34 ч	87- 94 м	91- 15.7 м 66 с	95- 1.65 ч	101- 8.5 ч	107- 6.7 ч	113- 118 д 21 м	119- 4.25 д 15.9 ч	125- 18 ч 55 с	131- 11.5 д	135- 22 ч	139- 5.5 ч	145 340 д	151- 150 д	157- 8.2 ч	163- 75 м	167- 17.7 м 74 м	173- 23.6 ч	179- 30 м 5.2 м
-4		6 ☆	10- 19.1 с	14- 72 с	18- 1.5 с		26- 2.1 с	30- 1.5 с		38(-) 0.66 с	44 ~10³ л	50 4.31	54 5.82	58 67.76	64 48.89	68- 280 д	74 0.87	78 0.354	84- 0.56	88- 85 д 10.8 мс	92 15.86	96 5.51	102 0.96	108 0.875	114 0.65	120 0.089	126 0.09	132 0.097	136 0.193	140- 3.3 д	146 α 5·10⁷ л	152 0.20	158 0.0902	164 1.56	168 0.140	174 0.163	180 0.135 5.5 мс
-3	3 0.0001	7- 53 д	11- 20.4 м	15- 123.95 с	19- 17.7 с	23- 11.9 с	27- 4.14 с	31- 2.66 с	35- 1.83 с	39- 1.0 с	45- 3.09 ч 5.8 мс	51- 27.8 д	55 2.6 г	59- ~10⁵ л	65- 245 д	69- 40.4 ч	75- 121 д	79- 34.5 ч 55 с	85- 64 д 70 м	89- 79.3 ч 4.4 м	93- >2 л 6.95 ч	97- 2.88 д	103 17 д	109 470 д	115 0.34	121- 17 д 154 д	127 [illegible] 75 с	133 7.2 г 38.8 ч	137- 8.7 ч 34.1 ч	141- 2.42 ч 63.7 с	147 15.07 1.3·10¹¹	153 236 д	159- 144.4 д	165- 10 ч	169- 31.8 д 46 с	175- 70 д	181 120.2 д
-2	4 99.9999	8 α ~10⁻¹⁵ с	12 98.892	16 99.759	20 90.92	24 78.7	28 92.21	32 95.0	36 0.337	40* 96.97	46 7.99	52 83.76	56 91.66	60 26.16	66 27.81	70 20.52	76 9.02	80 2.27	86 9.86	90* 51.46 0.83 с	94 9.12	98 1.87	104 10.97	110 12.39	116 14.24	122 2.46	128 1.919	134 2.42	138 0.25 9.9 мс	142* 27.11	148 11.27	154 2.15	160 2.294	166 33.41	170 3.03	176 5.21	182 26.41
-1	5 ☆	9 100	13 1.108	17 0.037	21 0.257	25 10.13	29 4.70	33 0.76	37 3.50 д	41 1.1·10⁵ л	47 7.32	53 9.55	57 2.19	61 1.25	67 4.11	71 11.4 д 20.3 мс	77 7.58 17.5 с	81 2·10⁵ л 13 с	87 7.02 2.8 ч	91 11.23	95 15.7	99 12.72	105 22.33	111 12.75 48.6 м	117 7.57 14 д	123 0.87 [illegible]	129 26.44	135 6.59 28.7 ч	139 ~140 д 55 с	143 12.17	149 13.82	155 14.73	161 18.88	167 22.94 2.5 с	171 14.31	177 18.56	183 14.4 5.5 с
0	6+ 0.82 с	10+ 2.7·10⁶ л	14+ 5.6·10³ л	18 0.204	22 8.82	26 11.17	30 3.09	34 4.22	38* 0.063	42 0.64	48 73.99	54 2.38	58 0.33	62 3.66	68 18.57	72 27.43	78 23.52	82 11.56	88* 82.56	92 17.11	96 16.5	100 12.62	106 27.33	112 24.07	118 24.01	124 4.61	130 4.08	136 7.81	140* 88.48	144 23.85 5·10¹⁵ л	150 7.47	156 20.47	162 25.53	168 27.07	172 21.82	178 27.1 4.8 с	184 30.64
+1		11+ 13.57 с	15+ 2.25 с	19+ 29.4 с	23+ 37.6 с	27+ 9.45 м	31+ 2.62 ч	35+ 86.3 д	39+ 265 л	43 0.145	49 5.46	55+ 3.52 м	59+ 45.1 д	63+ 125 л	69+ 57 м 13.8 ч	73 7.76 0.53 с	79+ 3.91 м 6.5·10⁴ л	83 11.55 114 м	89 50.5 д ~110 д	93+ 1.1·10⁶ л	97 9.45	101 17.07	107+ 7·10⁶ л 23 с	113* 12.26 5.1 г	119 8.58 175 д	125 6.99 58 д	131 21.18 12 д	137 11.32 2.6 м	141 32.5 д	145 8.30	151 ~93 г	157 15.68	163 24.97	169 9.4 д	173 16.13	179 13.75 19 с	185 78.5 д 1.62 м
+2			16+ 0.74 с	20+ 13.6 с	24+ 3.38 м	28+ 21.2 ч	32+ ~710 л	36* 0.014	40 99.6	44 2.06	50 5.25	56+ 5.94 м	60+ 3·10⁵ л	64 1.16	70 0.62	74 36.54	80 49.82	84 56.90	90+ 27.7 г	94 17.40	98 23.75	102 31.61	108 26.71	114 28.86	120 32.97	126 18.71	132 26.89	138* 71.66	142 11.07	146 17.22	152 26.63	158 24.87	164 28.18	170 14.88	174 31.84	180 35.22 5.5 ч	186 28.41
+3								37+ 5.07 м	41+ 110 м	45+ 164 д	51+ 5.79 м		61+ 5.5 м	65+ 2.564 ч	71+ 2.45 м 4 ч	75+ 82 м 48 с	81+ 18.2 м 56.8 м	85+ 10.3 г 4.36 ч	91+ 9.7 ч	95+ 65 д	99+ 66 ч	103+ 39.8 д	109+ 13.5 ч 4.75 м	115+ 53 ч 43 д	121+ 27.5 ч >5 л	127+ 9.4 ч 105 д	133+ 5.27 д 54 ч	139+ 85 м	143+ 33 ч	147+ 11.06 д	153+ 47.1 ч	159+ 18 ч	165+ 139.2 м 1.25 м	171+ 7.8 ч	175+ 101 ч 72 мс	181+ 42.45 д	187+ 24 ч
+4								38 2.87 ч	42+ >3.5 г	46 0.0033				66+ 54.8 ч	72+ 46.5 ч	76 7.76	82 9.19	86* 17.37	92+ 2.6 ч	96 2.80	100 9.67	104 18.58	110 11.81	116 7.58	122 4.71	128 31.79	134 10.44	140+ 12.8 д	144+ 285 д	148 5.72	154 22.53	160 21.9	166+ 82 ч	172+ 49.8 ч	176 12.73	182+ 9·10⁶ л	188+ 69.5 д
+5										47+ 4.7 д					73+ <2 м	77+ 11.3 ч 54 с	83+ 26 м 70 с	87+ 78 м 71 с	93+ 7.54 м	97+ 17 ч	101+ 14.6 м	105+ 4.5 ч	111+ 22 м 5.5 ч	117+ 50 м 2.9 ч	123+ 39.5 м 136 д	129+ 72 м 33.5 д	135+ 9.13 ч 15.6 м	141+ 18 м	145+ 3 м	149+ 2 ч	155+ 21.9 м	161+ 3.6 м	167+ 4.4 м		177+ 1.9 ч 6.4 с	183+ 64 м	
+6										48 0.185						78+ 86 м	84+ 3.3 м	88+ 2.77 ч	94 1.3 м	98+ ~1 м	102+ 11.5 м	106 1 г	112+ 21 ч	118+ 50 м	124 5.98	130 34.48	136* 8.87	142+ 11 м	146+ 13.9 м	150 5.60	156+ 9 ч	162+ >1 г					
+7										49+ 8.8 м							85+ 39 с	89+ 3.18 м	95+ 0.7 м	99+ 30 с		107+ 4.6 м	113+ 1.5 м	119+ 10 м 2.9 м	125+ 9.4 д 9.5 м	131+ 24.8 м 30 ч	137+ 3.9 м	143+ <0.5 м		151+ 12 м	157+ 0.5 м						
+8																		90+ 33 с				108+ ~4.3 м	114+ 2.4 м		126+ 10⁵ г	132+ 77.7 ч	138+ 17 м	144+ <10 с?	148+ 1.2 м								
+9																	87+ 17 с	91+ 9.8 с	97+ 0.3 м?		105+ <2 м		115+ 45 с	121+ 3.5 м	127+ 2.1 ч	133+ 2 м 63 м	139+ 41 с										
+10																		92+ 3 с							128+ 57 м	134+ 44 м	140+ 16 с										
+11																		93+ 2 с							129+ 1 ч 8.8 м	135+ <2 м	141+ 1.7 с										
+12																		94+ ~1 с							130+ 2.6 м		142+ ~1.5 с?										
+13																		95+ ~1 с?							131+ 3.4 м		143+ 1 с										
+14			2α						6α										5α						132+ 2.2 м		144+ ~1 с		4α								
+15	☆ T<10⁻²⁰ с								*20 n									97+ ~1 с	*50 n					*Tε=>10¹⁵ д		*Tm=104 д		*82 n									
ΔM		4=α	4	4	4	4	4	4	4	4	6	6	4	4	6	4	6	4	6	4	4	(6)4	(4)6	6	6	6	6	6	4	4	6	6	6	6	4	6	6

TABLE I
(cont'd)

2b	3a	3b
III	IV	V

ΔZ=20 ΔZ=24 ΔZ=24?

odd Z

(т) мо-милли- -минута, -час, -год

ith magic neutrons

Ru	44	[illegible]
Pd	46	98- 17 м; 99- 21.6 м; 100- 4.1 д; 101- 8.5 ч; 102 0.96; 103 17 д; 104 10.97; 105 22.33; 106 27.33; 107+ $7\cdot10^6$ л 23 с; 108 26.71; 109+ 13.5 ч 4.75 м; 110 11.81; 111+ 22 м 5.5 ч; 112+ 21 ч; 113+ 1.5 м; 114+ 2.4 м; 115+ 45 с
Cd	48	104- 59 м; 105- 55 м; 106 1.215; 107- 6.7 ч; 108 0.875; 109 470 д; 110 12.39; 111 12.75 48.6 м; 112 24.07; 113* 12.26 5.1 г; 114 28.86; 115+ 53 ч 43 д; 116 7.58; 117+ 50 м 2.9 ч; 118+ 50 м; 119+ 10 м 2.9 м; 121+ 3.5 м
Sn	50	108- 9 м; 109- 18.1 м; 110- 4 ч; 111- 35 м; 112 0.95; 113- 118 д 21 м; 114 0.65; 115 0.34; 116 14.24; 117 7.57 214 д; 118 24.01; 119 8.58 175 д; 120 32.97; 121+ 27.5 ч >5 л; 122 4.71; 123+ 39.5 м 136 д; 124 5.98; 125+ 9.4 д 9.5 м; 126+ 10^5 л; 127+ 2.1 ч; 128+ 57 м; 129+ 1 ч 8.8 м; 130+ 2.6 м; 131+ 3.4 м; 132+ 2.2 м
Te	52	114- 16 м; 115- 6 м; 116- 2.5 ч; 117- 1.1 ч; 118- 6.0 д; 119- 4.25 д 15.9 ч; 120 0.089; 121- 17 д 154 д; 122 2.46; 123 0.87 $24\cdot10^{13}$ л; 124 4.61; 125 6.99 58 д; 126 18.71; 127+ 9.4 ч 105 д; 128 31.79; 129+ 72 м 33.5 д; 130 34.48; 131+ 24.8 м 30 ч; 132+ 77.7 ч; 133+ 2 м 63 м; 134+ 44 м; 135+ <2 м
Xe	54	121- 40 м; 122- 19.5 ч; 123- 1.8 ч; 124 0.096; 125- 18 ч 55 с; 126 0.09; 127 36.4 д 75 с; 128 1.919; 129 26.44 8 д; 130 4.08; 131 21.18 12 д; 132 26.89; 133+ 5.27 д 54 ч; 134 10.44; 135+ 9.13 ч 15.6 м; 136* 8.87; 137+ 3.9 м; 138+ 17 м; 139+ 41 с; 140+ 16 с; 141+ 1.7 с; 142+ ~1.5 с?; 143+ 1 с; 144+ ~1 с
Ba	56	126- 97 м; 127- 12 м; 128- 2.4 д; 129- 2.45 ч; 130 0.101; 131- 11.5 д; 132 0.097; 133 7.2 г 38.8 ч; 134 2.42; 135 6.59 28.7 ч; 136 7.81; 137 11.32 2.6 м; 138 71.66; 139+ 85 м; 140+ 12.8 д; 141+ 18 м; 142+ 11 м; 143+ <0.5 м; 144+ <10 с?
Ce	58	131- 30 м; 132- 4.2 ч; 133- 6.3 ч; 134- 72 ч; 135- 22 ч; 136 0.193; 137- 8.7 ч 34.1 ч; 138 0.25 9.9 мс; 139 140 д 55 с; 140 88.48; 141 32.5 д; 142 11.07; 143+ 33 ч; 144+ 285 д; 145+ 3 м; 146+ 13.9 м; 148+ 1.2 м; 4α
Nd	60	137- 55 м; 138- 22 м; 139- 5.5 ч; 140- 3.3 д; 141- 2.42 ч 63.7 с; 142 27.11; 143 12.17; 144 23.83 $5\cdot10^{15}$ л; 145 8.30; 146 17.22; 147+ 11.06 д; 148 5.72; 149+ 2 ч; 150 5.60; 151+ 12 м
Sm	62	141- ~1 ч; 142- 72 м; 143- 9 м 137 с; 144 3.16; 145 340 д; 146 α $5\cdot10^7$ л; 147 α $1.5\cdot10^{11}$ л; 148 11.27; 149 13.82; 150 7.47; 151 ~93 г; 152 26.63; 153+ 47.1 ч; 154 22.53; 155+ 21.9 м; 156+ 9 ч; 157+ 0.5 м
Gd	64	144- 1 ч; 145- 25 м; 146- 46 д; 147- 29 ч; 148 α ~130 л; 149- α 9.3 д; 150 α $3\cdot10^5$ л; 151- 150 д; 152 0.20; 153 236 д; 154 2.15; 155 14.73; 156 20.47; 157 15.68; 158 24.87; 159+ 18 ч; 160 21.9; 161+ 3.6 м; 162+ >1 г
Dy	66	149 ~15 м; 150- α 7 м; 151- α 19 м; 152- α 2.3 ч; 153- α 5 ч; 154- α 13 ч; 155- 10 ч; 156 0.0524; 157- 8.2 ч; 158 0.0902; 159- 144.4 д; 160 2.294; 161 18.88; 162 25.53; 163 24.97; 164 28.18; 165+ 139.2 м 1.25 м; 166+ 82 ч; 167+ 4.4 м
Er	68	158- 2.5 ч; 160- 29 ч; 161- 3.1 ч; 162 0.136; 163- 75 м; 164 1.56; 165- 10 ч; 166 33.41; 167 22.94 2.5 с; 168 27.07; 169 9.4 д; 170 14.88; 171+ 7.8 ч; 172+ 49.8 ч
Yb	70	164,165 65 м; 166- 54 ч; 167- 17.7 м 74 м; 168 0.140; 169- 31.8 д 46 с; 170 3.03; 171 14.31; 172 21.82; 173 16.13; 174 31.84; 175+ 101 ч 72 мс; 176 12.73; 177+ 1.9 ч 6.4 с
Hf	72	169,170 112 м; 171- 16 ч; 172 ~5 л; 173- 23.6 ч; 174 0.163; 175- 70 д; 176 5.21; 177 18.56; 178 27.1 4.8 с; 179 13.75 19 с; 180 35.22 5.5 ч; 181+ 42.45 д; 182+ $9\cdot10^6$ л; 183+ 64 м
W	74	176- 1.7 ч; 177- 130 м; 178 21.5 д; 179- 30 м 5.2 м; 180 0.135 5.5 мс; 181 120.2 д; 182 26.41; 183 14.4 5.5 с; 184 30.64; 185 76.5 д 1.62 м; 186 28.41; 187+ 24 ч; 188+ 69.5 д
Os	76	180- (30 ч); 181- 23 м (2 ч); 182 21.9 ч; 183- 13.5 ч (10 ч); 184 0.018; 185- 93.6 д (500 д); 186 1.59; 187 1.64; 188 13.3; 189 16.1 5.7 ч; 190 26.4 9.5 м; 191 14.6 д 14 ч; 192* 41.0; 193+ 30.6 ч; 194+ ~700 д; 195+ 6.5 м
Pt	78	184- (2.3 ч); 185- <20 м; 186- 2.5 ч; 187- (2 ч); 188- 10 д; 189- 11 ч; 190- 0.0127 $6.9\cdot10^{11}$ л; 191- 3 д; 192 0.78 10^{15} л; 193 <500 л 4.3 д; 194* 32.9; 195 33.8 3.5 д; 196 25.2; 197+ 17.4 ч 88 м; 198 7.19; 199+ 31 м 14.1 с; 200+ 11.5 ч
Hg	80	189- 23 м; (190) (1.5 ч); 191- 55 м; 192- 5.7 ч; 193- 6 ч 10 ч; 194- 145 д 0.4 с; 195- 9.5 ч 40 ч; 196 0.146; 197- 65 ч 24 ч; 198 10.02; 199 16.84 42 м; 200 23.13; 201 13.22; 202 29.8; 203+ 46.9 д; 204 6.85; 205+ 5.5 м; 206+ (>10^3 л) 7.5 м
Pb	82	194- 11 м; 195- 17 м; 196- 37 м; 197- (~20 м) 42 м; 198- 2.4 ч; 199- 90 м 12.2 м; 200- 21.5 ч; 201- 9.4 ч 61 с; 202- ~$3\cdot10^5$ л 3.62 ч; 203- 52.1 ч 6.1 с; 204 1.48 66.9 м; 205 $3\cdot10^7$ л 5 мс; 206 23.6; 207 22.6 0.8 с; 208* 52.3; 209+ 3.3 ч; 210+ 23.3 г; 211+ 36.1 м; 212+ 10.64 ч; 214+ 26.8 м; 3α
Po	84	192- α 0.5 с; 194- α 13 с; 195- α 30 с; 196- α 1.9 м; 197- α ~4 м; 198- α 7 м; 199- α 11.7 м; 200- α 8 м; 201- 17.5 м; 202- 44.5 м; 203- α 42 м; 204- 3.54 ч; 205- α 1.8 ч; 206- α 8.8 д; 207- α 6.2 ч; 208- α 2.93 г; 209- α 103 г; 210* α 138.401 д; 211 0.52 с 25 с; 212 α $0.4\cdot10^{-7}$ с; 213 α $4.2\cdot10^{-6}$ с; 214 α $1.64\cdot10^{-4}$ с; 215+ α $1.83\cdot10^{-3}$ с; 216 α 0.158 с; 217+ α <10 с; 218+ α 3.05 м
Rn	86	204- α 3 м; 206- 6.5 м; 207- 11 м; 208- 23 м; 209- α 30 м; 210- α 2.7 ч; 211- 16 ч; 212* 23 м; 213- ?; 214 α ?; 215- α ~10^{-6} с; 216 α 10^{-4} с; 217 α 10^{-3} с; 218 α 0.019 с; 219+ α 3.92 с; 220 α 51.5 с; 221+ α 25 м; 222 α 3.8229 д; 223+ α 12 м; 224+ α 4.9 ч
Ra	88	213- α 2.7 м; 218 α ?; 219- α 10^{-3} с; 220 α 0.03 с; 221 α 30 с; 222 α 38 с; 223 α 11.68 д; 224 α 3.64 д; 225+ 14.8 д; 226- 1617 л; 227+ 41.2 м; 228+ 6.7 г; 229+ <1 м; 230+ 1 ч
Th	90	223- α ~0.9 с; 224 α ~1 с; 225- α 8 м; 226 α 30.9 м; 227 α 18.17 д; 228 α 1.91 г; 229 α 7340 л; 230 α $8\cdot10^4$ л; 231+ 25.64 ч; 232 100 $1.39\cdot10^{10}$ л; 233+ 22.12 м; 234+ 24.1 д; 235+ <5 м
U	92	227- α 1.3 м; 228- α 9.3 м; 229- α 58 м; 230 α 20.8 д; 231- α 4.3 д; 232 α 74 л; 233 α $1.62\cdot10^5$ л; 234 $2.48\cdot10^5$ л $2\cdot10^{16}$ л; 235 0.7205 $7.1\cdot10^8$ л $1.9\cdot10^{17}$ л; 236 $2.39\cdot10^7$ л $2\cdot10^{16}$ л; 237+ 6.75 д; 238 99.2739 $4.51\cdot10^9$ л $8\cdot10^{15}$ л; 239- 23.54 м; 240- 14.1 ч
Pu	94	232- α 36 м; 233- α 20 м; 234- α 9 ч; 235- α 26 м; 236 α 2.85 г $3.5\cdot10^9$ л; 237 45.6 д; 238 86.4 г $4\cdot10^{10}$ л; 239 24360 л $5.5\cdot10^{15}$ л; 240 6580 л $1.2\cdot10^{11}$ л; 241+ α 13 л; 242 $3.79\cdot10^5$ л $7\cdot10^{10}$ л; 243- 4.98 ч; 244 $7.6\cdot10^7$ л $2.5\cdot10^{10}$ л; 245+ 10.1 ч; 246+ 10.85 д
Cm	96	238- α 2.5 ч; 239- 2.9 ч; 240 α 26.8 д $1.9\cdot10^6$ л; 241- α 35 д; 242 α 162.5 д $7.2\cdot10^6$ л; 243- α 35 л; 244 17.6 л $1.4\cdot10^7$ л; 245 9320 л $1.2\cdot10^7$ л; 246 5480 л $2\cdot10^7$ л; 247 ~$4\cdot10^7$ л; 248* $4.7\cdot10^5$ л $4.6\cdot10^6$ л; 249- 64 м; 250 ~$2\cdot10^4$ л
Cf	98	244 25 м; 245- α 44 м; 246 α 35.7 ч $2.1\cdot10^3$ л; 247- 2.5 ч; 248 350 д $1.5\cdot10^4$ л; 249 360 л $1.5\cdot10^9$ л; 250 10.9 л $1.5\cdot10^4$ л; 251 800 л; 252 2.2 г 66 л; 253- 17 д; 254 α=? 55 д
Fm	100	248 α 30 с; 249 α 2.5 м; 250 α 30 м; 251- α 7 ч; 252 22.7 ч >8 л; 253- α ~4.5 д; 254 3.24 ч 246 д; 255 21.5 ч >60 л; 256 α=? 2.7 ч; 257 α, Φ 3 м; 258 α, Φ 10 ч; 260 λ, Φ
E-Yb	102	254 α, Φ 3 с; 256 α 8 с; 258 α, Φ; 260 α, Φ; 261 α, Φ; 262 α, Φ; 263 α, Φ; 264 α, Φ; 266 α, Φ
E-Hf	104	264 α, β; 266 α, Φ; 267 α, Φ; 268 α, Φ; 269 α, Φ; 270 α, Φ; 272 α, Φ
E-W	106	270 α, Φ; 272 α, Φ; 273 α, Φ; 274 α, Φ; 276 α, (+); 276* α, (+); 2α

*T_ε => 10^{15} л; *T_m = 104 л; *82 n; *116 n; *126 n; *T_m = 26.2 м; *152 n; 158*170 n?

(4)6	6	6	6	6	6	4	4	6	6	6	6	4	6	6	6	4	6	6	6	6	4	6	6	6	6	4	6	6	6	6

E I

t'd)

THE PERIODIC SYSTEM OF ISOTOPES

II	1a	Ib								2a									
Периоды	0	I								II									
Элементы	H	Li	B	N	F	Na	Al	P	Cl	K	Sc	V	Mn	Co	Cu	Ga	As	Br	Rb
A / Z	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37
−19																			
−18																			
−17																			
−16																			
−15																			
−14																			
−13																			
−12																			
−11																			
−10																			
−9																			
−8															57− 0.18 с				
−7															58− 9.5 м 3.04 с		68− ~7 м		
−6												45− ~1 с			59− 81.5 с		69− 15 м	(73−) 4 м	79− 20.9 м
−5											40− 0.22 с	46− 0.4 с	50− 0.28 с	54− 0.18 с	60− 23.4 м	64− 2.6 м	70− 47 м	74− 26 м	80− 34 с
−4											41− 0.873 с	47− 31.1 м	51− 45.2 м	55− 18.2 ч	61− 3.3 ч	65− 15.2 м	71− 62 ч	75− 1.6 ч	81− 4.7 ч 31.5 м
−3			8 β^+,2α 0.78 с	12− 0.0125 с	16 п=рвд.? <1 мс	20− β^+,α 0.385 с	24− β^+,α 2.10 с	28− 0.28 с	32− β^+,α 0.306 с		42− 0.68 с	48− 16 д	52− 5.72 д 21.3 м	56− 77.3 д	62− 9.73 м	66− 9.45 ч	72− 26 ч	76− 16.1 ч	82− 1.25 м 6.3 ч
−2	1 99.985	5 ✳	9 ✳	13− 10.08 м	17− 70 с	21− 22.8 с	25− 7.3 с	29− 4.45 с	33− 2.8 с	37− 1.2 с	43− 3.92 ч	49− 330 д	53− $2\cdot10^6$ л	57− 267 д	63 69.1	67− 77.9 ч	73− 76 д 20 мс	77− 57 ч	83− 83 д
−1	2 0.015	6 7.42	10 19.61	14 99.634	18− 111 м	22− 2.58 г	26− $8\cdot10^5$ л 6.7 с	30− 2.53 м	34− 1.53 с 32.4 м	38− 0.95 с 7.7 м	44− 3.92 ч 2.44 д	50− 0.25 $\sim10^{16}$ л	54− 291 д	58− 71.3 д 9.2 ч	+64− 12.8 ч	~68 68 м	+74− 17.5 д 8 с	78− 6.25 м 0.118 мс	+84− 33 д 23 м
0	3 12.26 г	7 92.58	11 80.39	15 0.366	19 100	23 100	27 100	31 100	35 75.53	39* 93.10	45 100	51 99.75	55 100	59 100	65 30.9	69 60.4	75 100 16 мс	79 50.537	85 72.15
+1		8+ β^-,2α 0.841 с	12+ β^-,α 18.5 мс	16+ 7.35 с	20+ 11.4 с	24+ 14.97 ч 0.02 с	28+ 2.27 м	32+ 14.22 д	36− $3.08\cdot10^5$ л	−40+ $1.25\cdot10^9$ л 0.0118	46+ 83.9 д 19.5 с	52+ 3.76 м	56+ 2.567 ч	60+ 5.24 м 10.47 г	66+ 5.1 м	70− 21.1 м	76+ 26.8 ч	←18 м− 4.5 ч 5 с	86− 18.66 д 1.02 м
+2		9+ β^-,n2α 0.168 с	13+ 35 мс	17+ β^-,n 4.15 с	21+ 5 с	25+ 60 с	29+ 6.56 м	33+ 24.4 д	37 24.47	41 6.88	47+ 3.43 д	53+ 2 м	57+ 1.7 м	61+ 99 м	67+ 58.5 ч	71 39.6	77+ 38.7 ч	81 49.463	87* 27.85 $5\cdot10^{10}$ л
+3						26+ 1.04 с	30+ 3.27 с	34+ 12.4 с	38+ 37.29 м 1 с	42+ 12.52 ч	48+ 44 ч	54+ 55 с		62+ 13.9 м 1.6 м	68+ 32 с	72+ 14.3 ч	78+ 91 м	82+ 35.8 ч	88+ 17.8 м
+4									39+ 55.5 м	43+ 22.4 ч	49+ 57 м			63+ 84 м		73+ 4.85 ч	79+ 9.1 м	83+ 144.6 м	89+ 14.9 м
+5									40+ 1.4 м	44+ 22 м	50+ 1.5 м			64+ 8 м 2 м		74+ 8 м	80+ 15.3 с	84+ 31.8 м 6 м	90+ 2.74 м
+6										45+ 34 м						75+ 1.5 м?	81+ 33 с	85+ 3 м	91+ 14 м 1.67 м
+7																76+ <1 м		86+ ~2 м?	92+ 5.3 с
+8																		87+ β^-,n 55.6 с	93+ 5.6 с
+9																		88+ β^-,n 15.5 с	94+ ~5 с?
+10																	85 0.43 с	89+ β^-,n 4.51 с	95+ ~1 с?
+11																		90+ β^-,n 1.4 с	
+12																			97+ ~1 с?
+13																			
+14		2α						6α										5α	
+15									*20 n										*50 n
ΔM	4=α	4	4	4	4	4	4	4	4	6	6	4	4	6	4	6	4	6	4

II	2b													
Периоды	III													
Элементы	Y	Nb	Tc	Rh	Ag	In	Sb	J	Cs	La	Pr	Pm	Eu	T…
A / Z	39	41	43	45	47	49	51	53	55	57	59	61	63	6…
−19														
−18														
−17														
−16														
−15														
−14														
−13														
−12														
−11														
−10							(111)− ~1 м?	(117−) ~10 м	123− 6 м				143− ~1.5 ч	
−9						(104)− 5.7 м	112− 0.9 м	118− ~19 м	124− ~1 м?	130− ~14 м			144− 18 м	
−8				95− ~2 м	101− 2 м	105− ~2 м	113− 7 м	119− 21 м	125− 45 м	131− 6? м			145 5 д	
−7	82− 70 м			96(−) ~11 м	102− 16 м	106− 5.3 м	114− 3.3 м	120− 2 ч	126− 1.6 м	132− 4.5 ч			146− (4.4 д) (38 ч)	
−6	83(−) 3.5 ч			97− 35 м	103− 66 м	107− 30 м	115− 31 м	121− 2.1 ч	127− 6.3 ч	133− 4 ч	135− 22 м	141− 20 м	147− α 24 д	
−5	84− 3.7 ч		92− 4.3 м	98− 8.7 м	104− 1.2 ч 27 м	108− 40 м 55 м	116− 16 м 1 ч	122− 3.5 м	128− 3.9 м	134− 6.5 м	136− 70 м	142− 30 с	148− 54 д	
−4	85− 3.1 ч 5 ч	89− 1.9 ч 0.8 ч	93− 2.75 ч 43.5 м	99− 4.7 ч 16 д	105− 40 д	109− 4.3 ч 1.3 м	117− 2.8 ч	123− 13 ч	129− 30.7 ч	135− 19.5 ч	137− 1.4 ч	143− 270 д	149− 106 д	
−3	86− 14.6 ч 49 м	24 с 14.6 ч 0.015 с	94− 53 м 4.5 ч	100− 20.8 ч	106− 8.2 д 24 м	110− 66 м 5 ч	118− 5.1 ч 3.5 м	124 4.2 д	130− 30 м	136− 9.5 м	138− 2 ч	144 450 д	150− 15 ч	
−2	87− 80 ч 14 ч	91− 8 л 64 д	95− 20 ч 60 д	101− 4.3 ч 4.7 д	107 51.35 44.3 с	111− 2.81 д 10 м	119− 38 ч	125 60 д	131 9.6 д	137 $6\cdot10^4$ л	139− 4.5 ч	145 18 л	151 47.82	
−1	104 д 14 мс 0.3 мс	13 ← 10.1 д 191 м	96− 4.2 д 51.5 м	+102− 210 д	108− 2.3 м ~5 л	+112− 15 м 20.7 м	120− 16.6 м 5.8 д	+126− 13 д (2.6 ч)	132− 6.2 д	+138− 0.089 $1\cdot10^{11}$ л	140− 3.4 м	146− ~1 г	+152− 12.7 г 9.2 ч	
0	89* 100 16.1 с	93 100 3.7 г	97 $2.6\cdot10^6$ л 91 д	103 100 57 м	109 48.65 39.2 с	113 4.28 112 м	121 57.25	127 100	133 100	139* 99.911	141* 100	147+ 2.64 г	153 52.18	15… 100
+1	90+ 64.2 ч 3.19 ч	94− $1.8\cdot10^4$ л 6.6 м	98+ $1.5\cdot10^6$ л	104+ 44 с 4.4 м	110+ 24.2 с 253 д	+72 с− 49 д 42 мс	+122− 2.8 д 3.5 м	128+ 24.99 м	134+ 2.07 г 3.2 ч	140+ 40.22 ч	142+ 19.2 ч	148+ 5.3 д 42 д	154+ 16 л	160 72.3
+2	91+ 57.5 д 50.3 м	95+ 35 д 84 ч	99+ $2.12\cdot10^5$ л 6.04 ч	105+ 36.5 ч 45 с	111+ 7.6 д 74 с	115 95.77 $6\cdot10^{14}$ л 4.52 ч	123 42.75	129+ $1.72\cdot10^7$ л	135+ $3\cdot10^6$ л	141+ 3.8 ч	143+ 13.76 д	149+ 54 ч	155+ 1.7 г	161 6.88
+3	92+ 3.6 ч	96+ 23.35 ч	100+ 15.8 с	106+ 30 с 133 м	112+ 3.2 ч	53.99 м 14 с 2.5 с	60.2 д 1.3 м 21 м	130+ 12.6 ч	136+ 12.9 д	142+ 85 м	144+ 17.27 м	150+ 2.7 ч	156+ 15.4 д	162 14 м
+4	93+ 10.4 ч	97+ 72.1 м 60 с	101+ 14.3 м	107+ 24 м	113+ 5.3 ч 1.2 м	117+ 38 м 1.9 ч	125+ 2 г	131+ 8.08 д	137+ 26.6 г	143+ ~19 м	145+ 5.95 ч	151+ 27.5 ч	157+ 15.4 ч	163 6.5
+5	94+ 16.5 м	98+ 51.5 м	102+ 4.5 м 5 с	108+ 18 с	114+ 2 м 5 с	118+ 4.5 м 5.1 с	126+ 11 д 19 м	132+ 2.3 ч	138+ 32.2 м	144+ ~1 м?	146+ 24.4 м	152+ 6.5 м	158+ 60 м	
+6	95+ 10.5 м	99+ 2.4 м	103+ 1.2 м	109+ ~25 с	115+ 21.1 м ~20 с	119+ 17.5 м 2.3 м	127+ 88 ч	133+ 20.9 ч	139+ 9.5 м			153+ 12.5 ч	159+ 20 м	
+7	96+ 2.3 м	100+ 3 м	104+ 18 м	110+ ~3.6 с	116+ 2.5 м	120+ ~55 с	128+ 9.9 ч 9.9 м	134+ 52.4 м	140+ 66 с		148+ 12 м	154+ 2.5 м		
+8	97+ ~1 м?	101+ 1 м	105+ 10 м		117+ 1.1 м	(121)+ 30 с 3.1 м	129+ 4.2 ч	135+ 6.68 ч	141+ ~1 м?					
+9						(122)+ 7 с	130(+) 33 м 7.1 м	136+ 28.8 с	142+ ~1 м					
+10			107+ <1.5 м			(123)+ 10 с 36 с	131(+) 23.1 м	137+ β^-,n 22 с	143+ <1 м?					
+11						(124)+ ~5 с	132+ 2.1 м	138+ β^-,n 5.9 с	144+ <1 м					
+12							133+ 4.4 м	139+ β^-,n 2.7 с						
+13							134,135 + ~50 с							
+14									4α					
+15										*82 n				
ΔM	4	4	6	6	4(6)	8(6)	6	6	6(4)	2(4)	6	6	6	

TABLE I

even Z

		2b										3a												3b											
		III										IV												V											
Br	Rb	Y	Nb	Tc	Rh	Ag	In	Sb	J	Cs	La	Pr	Pm	Eu	Tb	Ho	Tu	Lu	Ta	Re	Ir	Au	Tl	Bi	At	Fr	Ac	Pa	Np	Am	Bk	Es	Md	Lw	E-Ta
35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105
																									198(-) α 43 с										
																									(201)(-) α 1.5 м										
																									(202)(-) 3 м										
															147- 24 м	(153)- 2-4 м							191- 10 м	197(-) α 1.7 м	203(-) α 7.2 м										
															148- 70 м							186- 15 м	192- 11 м	198- α 7 м	204- 9.3 м										
								(111)- ~1 м?	(117-) ~10 м	123- 6 м				143- ~1.5 ч	α 149- 4.1 ч 4.3 м	155- (45 м)						187- α 4.3 м	193- 22.6 м	199- α ~25 м	205- α 26 м										
							(104)- 5.7 м	112- 0.9 м	118- ~19 м	124- ~1 м?	130- ~14 м			144- 18 м	150- 3 ч	156(-) 50 м			172- 23.6 м		182- (15 м)	188- (4.5 м)	194- 33 м	200- 35 м	206- 29.5 м 2.9 ч										
					95- ~2 м	101- 2 м	105- ~2 м	113- 7 м	119- 21 м	125- 45 м	131- 61 м			145 5 д	151- α 18.5 ч		161- 32 м	167- 43 м	173- 3.7 ч	177- 17 м	183- 1 ч	189- 42 м	195- 1.2 ч 3.5 с	α 201- 1.85 ч 62 м	207- α 1.8 ч									257(-) α 8 с	
		82- 70 м			96(-) ~11 м	102- 16 м	106- 5.3 м	114- 3.3 м	120- 2 ч	126- 1.6 м	132- 4.5 ч			146- (4.4 д) (38 ч)	152- ~17 ч 4 м	158- (27 м)	(162)- <45 м	168- 7.1 м	174- 1.3 ч	178- 15 м	184- 3.1 ч	190- (21 м)	196- 1.8 ч 1.41 ч	202- 95 м	α 208- 6.3 ч 1.6 ч	212- α 19.3 м						246(-) α 7.3 м			
(73-) 4 м	79- 20.9 м	83(-) 3.5 ч			97- 35 м	103- 66 м	107- 30 м	115- 31 м	121- 2.1 ч	127- 6.3 ч	133- 4 ч	135- 22 м	141- 20 м	147- α 24 д	153- 62 ч	159(-) 33 м	163- 2 ч	169- 1.5 д	175- 11 ч	179- 20 м	185- 15 ч	191(-) 3 ч 2 с	197- 2.7 ч 0.54 с	203- α 11.8 ч	209- α 5.5 ч			225(-) α 2 с	231- ~50 м	237(-) α ~1.3 ч		247- 7 м			
74- 26 м	80- 34 с	84- 3.7 ч		92- 4.3 м	98- 8.7 м	104- 1.2 ч 27 м	108- 40 м 55 м	116- 16 м 1 ч	122- 3.5 м	128- 3.9 м	134- 6.5 м	136- 70 м	142- 30 с	148- 54 д	154- 17.2 ч 8 ч	160- 28 м 5.3 ч	164- <45 м	170- 2 д	176- 8 ч	180- 20 ч 2.4 м	186- 16 ч	192- 4.7 ч	198- 5.3 ч 1.9 ч	204- 11.2 ч	210- α 8.3 ч			226(-) 1.8 м	232- 13 м	238- 1.9 ч		248- α 25 м			
75- 1.6 ч	81- 4.7 ч 31.5 м	85- 3.1 ч 5 ч	89- 1.9 ч 0.8 ч	93- 2.75 ч 43.5 м	99- 4.7 ч 16 д	105- 40 д	109- 4.3 ч 1.3 м	117- 2.8 ч	123- 13 ч	129- 30.7 ч	135- 19.5 ч	137- 1.4 ч	143- 270 д	149- 106 д	155- 5.6 д	161- 2.5 ч	165- 29 ч	171- 600 д 8.5 д	177- 53 ч	181- 19 ч	187- 13 ч	193- 17.5 ч 3.9 с	199- 7.4 ч 42 мс	205- 14.5 д	211- α 7.2 ч		221(-) α <2 с	227- α 38.3 м	233- α 35 м	239- α 12 ч	243- α 4.5 ч	249- α 2 ч	255- α 30 м		
76- 16.1 ч	82- 1.25 м 6.3 ч	86- 14.6 ч 49 м	24 с- 14.6 ч 0.015 с	94- 53 м 4.5 ч	100- 20.8 ч	106- 8.2 д 24 м	110- 66 м 5 ч	118- 5.1 ч 3.5 м	124- 4.2 д	130- 30 м	136- 9.5 м	138- 2 ч	144 450 д	150 15 ч	156- 5.6 д 5.5 ч	162- 67 м	166- 7.7 ч	172- 6.7 д 4 ч	178- 2.1 ч 9.35 м	182- 64 ч 12.7 ч	188- 41.5 ч	194- 39.5 ч	200- 26.1 ч	206- 6.243 д	212- α 0.22 с		222(-) α 5.5 с	228- α 22 ч	234- α 4.4 д	240- α 51 ч	244- α 4.4 ч	250- 8 ч	256- 1.5 ч		
77- 57 ч	83- 83 д	87- 80 ч 14 ч	91- 8 д 64 д	95- 20 ч 60 д	101- 4.3 ч 4.7 д	107 51.35 44.3 с	111- 2.81 д 10 м	119- 38 ч	125 60 д	131 9.6 д	137 6·10⁴ л	139- 4.5 ч	145 18 л	151 47.82	157- >10² л	163- >10³ л 0.8 с	167- 9.6 д	173- 625 д	179 600 д	183- 67.6 д	189- 11 д	195- 180 д 30.6 с	201 72 ч 5 мс	207- 8.27 л 28 л	213 α(-) <2 с	217(-) <2 с	223- α 2.2 м	229 α 1.5 д	235 α 410 д	241 485 л 2·10⁴ л	245- α 4.98 д	251- α 1.5 д			
78- 6.25 м 0.118 мс	+84- 33 д 23 м	104 д 14 мс 0.3 мс	13 с 10.1 д 191 м	96- 4.2 д 51.5 м	+102- 210 д	108- 2.3 м ~5 л	+112- 15 м 20.7 м	120- 16.6 м 5.8 д	+126- 13 д (2.6 ч)	132- 6.2 д	+138- 0.089 1·10¹¹ л	140- 3.4 м	146- ~1 г	+152- 12.7 г 9.2 ч	158 >5 г 14.73 с	+164- >1 г? 36.7 м	+168- 85 д	174- 165 д (90 д)	180 0.0123 >10¹² л 8.15 ч	184- 50 д 2.2 д	190- 12.3 д 3.2 ч	+196- 5.6 д 9.8 ч	202- 12 д	208- 3·10⁵ л 2.5 мс	214(-) α 2·10⁻⁶ с	218(-) α 5·10⁻³ с	224- α 2.9 ч	+230- α 17.7 д	+236- 5·10³ л 22 ч	+242- 152 г 16.01 ч	246- 1.8 д	252(-) α 140 д			
79 50.537	85 72.15	89* 100 16.1 с	93 100 3.7 г	97 2.6·10⁶ л 91 д	103 100 57 м	109 48.65 39.2 с	113 4.28 112 м	121 57.25	127 100	133 100	139* 99.911	141* 100	147+ 2.64 г	153 52.18	159 100	165 100	169 100	175 97.41	181 99.9877 0.33 с	185 37.07	191 37.3 4.9 с	197 100 7.2 с	203 29.50	209* 100	215 α 10⁻⁴ с	219 α 0.02 с	225 α 10 д	231 α 3.43·10⁴ л	237 α 2.2·10⁶ л	243 α 7.35·10³ л	247 α 10 л	253 20.0 д 7·10⁵ л	259 α, Φ ?	265 α, Φ ?	271 α, Φ ?
+18 м- 4.5 ч 5 с	86- 18.66 д 1.02 м	90+ 64.2 ч 3.19 ч	94- 1.8·10⁴ л 6.6 м	98+ 1.5·10⁶ л	104+ 44 с 4.4 м	110+ 24.2 с 253 д	+72 с- 49 д 42 мс	+122- 2.8 д 3.5 м	128+ 24.99 м	134+ 2.07 г 3.2 ч	140+ 40.22 ч	142+ 19.2 ч	148+ 5.3 д 42 д	154+ 16 л	160+ 72.3 д	166+ 27.3 ч >30 л	170+ 129 д	2.59+ 2.4·10¹⁰ л 3.71 ч	182+ 115.1 д 16.5 м	-186+ 88.9 ч 1 ч	-192+ 74.37 д 1.42 м	198+ 2.697 д	+204- 3.56 г	α 210+ 2.6·10⁶ л 5.013 д	α 216(+) 3·10⁻⁴ с	220(-) α 27.5 с	-226+ 29 ч	232+ 1.31 д	238+ 2.1 д	-244+ 10.1 ч 26 м	-248+ 16 ч	-254+ 480 д 39 Ф			
81 49.463	+87* 27.85 5·10¹⁰ л	91+ 57.5 д 50.3 м	95+ 35 д 84 ч	99+ 2.12·10⁵ л 6.04 ч	105+ 36.5 ч 45 с	111+ 7.6 д 74 с	95.77+ 6·10¹⁴ л 4.52 ч	123 42.75	129+ 1.72·10⁷ л	135+ 3·10⁶ л	141+ 3.8 ч	143+ 13.76 д	149+ 54 ч	155+ 1.7 г	161+ 6.88 д	167+ 3 ч	171+ 680 д	177+ 6.75 д	183+ 5 д	187+ 62.93 1·10¹¹ л	193* 62.7 11.9 д	199+ 3.14 д	205 70.50	211+ α 2.16 м	217(+) α 0.018 с	221(+) α 4.8 м	227+ α 21.6 г	233+ 27 д	239+ 2.346 д	245+ 1.98 ч	249+ α Ф 314 д	255+ 24 д			273 ?
82+ 35.8 ч	88+ 17.8 м	92+ 3.6 ч	96+ 23.35 ч	100+ 15.8 с	106+ 30 с 133 м	112+ 32 ч	53.99 м 14 с+ 2.5 с	60.2 д 1.3 м+ 21 м	130+ 12.6 ч	136+ 12.9 д	142+ 85 м	144+ 17.27 м	150+ 2.7 ч	156+ 15.4 д	162+ 14 м 2 ч	168+ 3.3 м	172+ 63.6 ч	178+ 18.7 ч 4.5 м	184+ 8.7 ч	188+ 16.7 ч 18.7 м	19[illegible]+ 47.2 с 32 мс	200+ 48 м	206+ 4.19 м	212+ α 60.5 м	218(+) α ~1.3 с	222+ α 14.8 м	228+ 6.13 ч	234+ 6.66 ч 1.175 м	240+ 63 м 7.3 м	246+ 25 м	250+ 193.3 м	256+ нор.			
83+ 144.6 м	89+ 14.9 м	93+ 10.4 ч	97+ 72.1 м 60 с	101+ 14.3 м	107+ 24 м	113+ 5.3 ч 1.2 м	117+ 38 м 1.9 ч	125+ 2 г	131+ 8.08 д	137+ 26.6 г	143+ ~19 м	145+ 5.95 ч	151+ 27.5 ч	157+ 15.4 ч	163+ 6.5 ч 7 м	169+ 96 м	173+ 30 м 16 м	179+ 8 ч	185+ 48 м	189+ 150 д 22.6 ч	195+ 2.3 ч	201+ 26 м	207+ 4.79 м	213+ α 47 м	219+ α 0.9 м	223+ α 22 м	229+ 66 м	235+ 23.7 м	241+ 16 м 3.4 ч						
84+ 31.8 м 6 м	90+ 2.74 м	94+ 16.5 м	98+ 51.5 м	102+ 4.5 м 5 с	108+ 18 с	114+ 2 м 5 с	118+ 4.5 м 5.1 с	126+ 11 д 19 м	132+ 2.3 ч	138+ 32.2 м	144+ ~1 м?	146+ 24.4 м	152+ 6.5 м	158+ 60 м		170+ 40 с	(174)+ 5.5 м		186+ 10.5 м	190+ 2.8 м	196+ <5 ч?	202+ ~0.4 м	208+ 3.1 м	214+ α 19.7 м		224+ 2 м	230+ <1 м								
85+ 3 м	91+ 14 м 1.67 м	95+ 10.5 м	99+ 2.4 м	103+ 1.2 м	109+ ~25 с	115+ 21.1 м ~20 с	119+ 17.5 м 2.3 м	127+ 88 ч	133+ 20.9 ч	139+ 9.5 м			153+ 12.5 ч	159+ 20 м						191+ 10 м	197+ 7 м	203+ 55 с	209+ 2.2 м	215+ 8 м				237+ 39 м							
86+ ~2 м?	92+ 5.3 с	96+ 2.3 м	100+ 3 м	104+ 18 м	110+ ~3.6 с	116+ 2.5 м	120+ ~55 с	128+ 9.9 ч 9.9 м	134+ 52.4 м	140+ 66 с		148+ 12 м	154+ 2.5 м				(176)+ 2 м				198+ 50 с		210+ 1.32 м												
87+ β⁻,n 55.6 с	93+ 5.6 с	97+ ~1 м?	101+ 1 м	105+ 10 м		117+ 1.1 м	(121)+ 30 с 3.1 м	129+ 4.2 ч	135+ 6.68 ч	141+ ~1 м?																									
88+ β⁻,n 15.5 с	94+ ~5 с?						(122)+ 7 с	130(+) 33 м 7.1 м	136+ 28.8 с	142+ ~1 м																									
89+ β⁻,n 4.51 с	95+ ~1 с?			107+ <1.5 м			(123)+ 10 с 36 с	131(+) 23.1 м	137+ β⁻,n 22 с	143+ <1 м?																									
90+ β⁻,n 1.4 с							(124)+ ~5 с	132+ 2.1 м	138+ β⁻,n 5.9 с	144+ <1 м																									
	97+ ~1 с?							133+ 4.4 м	139+ β⁻,n 2.7 с																										
								134, 135 + ~50 с																											
	5α										4α										3α														2α
	*50 n										*82 n										*116 n			*126 n											
4	6	4	4	4	6	6	4(6)	8(6)	6	6	6(4)	2(4)	6	6	6	6	4	6	6	4(6)	6(4)	6	6	6	6	4	6	6	6	6	4	6	6	6	6

TABLE I

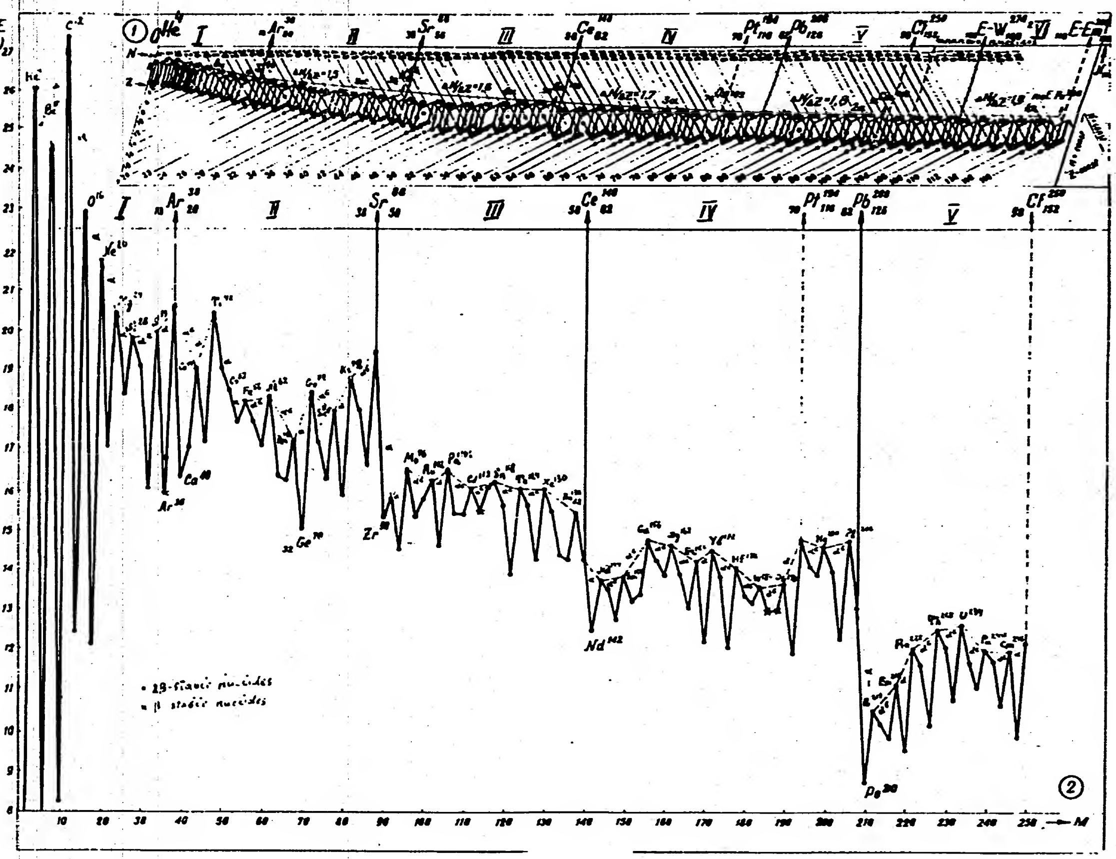

TABLE II

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THE PERIODIC SYSTEM OF ELEMENTS

by D.I. MENDELEEV

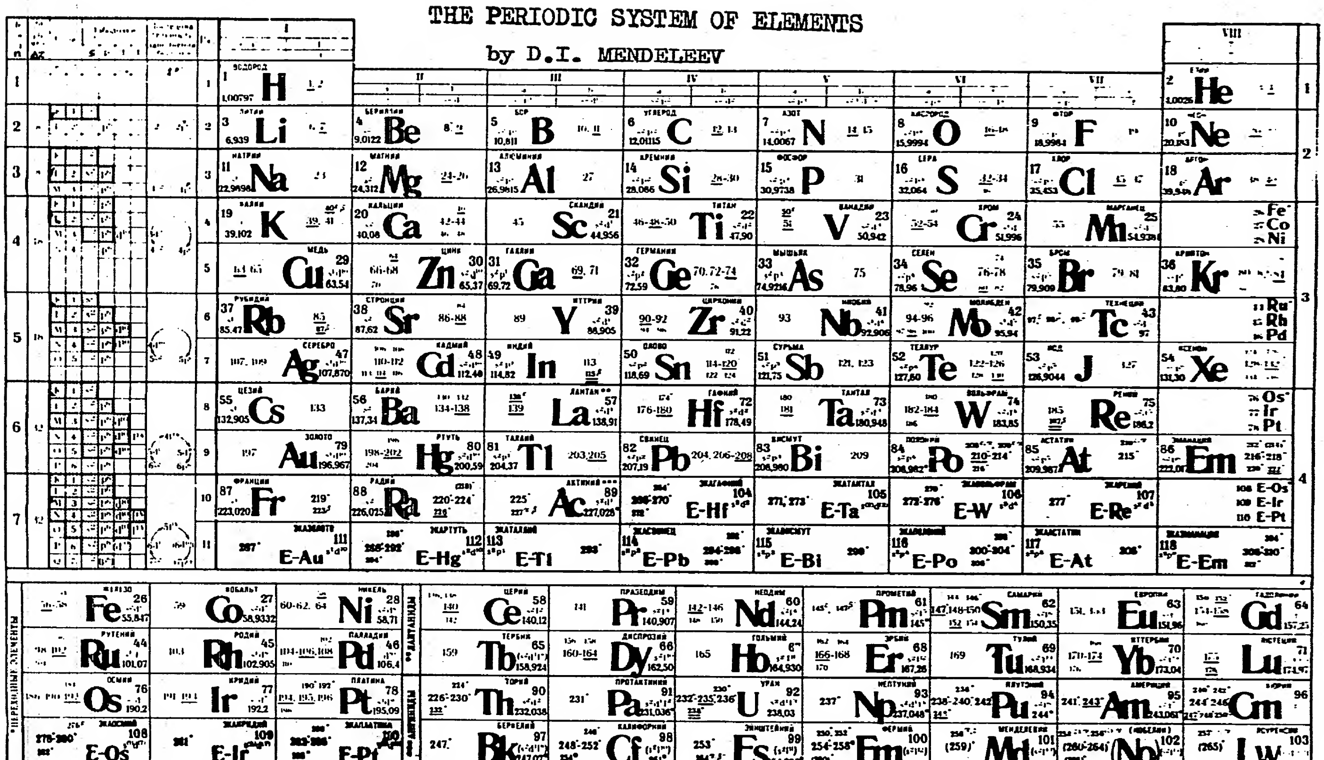

TABLE III

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